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Distribution, Abundance and Habitat Selection of Northern Pygmy and Barred Owls Along the Eastern Slopes of the Alberta Rocky Mountains

Alberta Species at Risk Report No. 91

Alberta
SUSTAINABLE RESOURCE DEVELOPMENT

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Mark D. Piorecky and David R. C. Prescott

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EXECUTIVE SUMMARY

Little is known about the distribution, population size and habitat use requirements of northern pygmy (*Glaucidium gnoma*) and barred (*Strix varia*) owls in Alberta. Both species are ranked as 'sensitive' by the province, which means they are not believed to be at immediate risk of extirpation or extinction but may require special attention or protection to prevent them from becoming at risk (CESCC 2001).

We conducted diurnal and nocturnal broadcast surveys to determine distribution, abundance and habitat selection of both species, over approximately 37 000 km^2 of Alberta's eastern slopes. Northern pygmy owls surveys lasted for eight weeks in 2001, during which time 1532 site visits were made. Forty-eight responses were recorded at 42 sites representing 40 individual northern pygmy owls. Barred owl surveys were conducted over three years (1999-2001), and consisted of over 1150 visits, at 527 unique sites. Summarizing all barred owl results, 63 barred owl responses were recorded at 54 sites, representing 45 unique individuals. The majority of sites were visited at least twice (316 of 527 unique sites).

Density estimates were produced using an analytical method that models variation in species detectability (*distance sampling*). Both species were widely distributed and occurred at low densities throughout the study area. Population densities were estimated as 0.048 birds/km^2 (95% CI: 0.017-0.135 birds/km^2) for northern pygmy owls, and 0.025 birds/km^2 (95% CI: 0.013-0.047 birds/km^2) for barred owls.

Predictive models of habitat selection were developed for each species using stepwise logistic and autologistic regression. Autologistic models accounted for observed spatial dependencies and as a result, produced better fitting models that more accurately reflect the role of predictor variables in influencing species occurrence. All models considered biophysical variable selection at two spatial scales (minimum and maximum home range). Northern pygmy owls showed a preference for older, structurally diverse mixedwood habitats, with line-of-sight enhanced by increased edge and terrain roughness. Models for barred owls initially suggested a preference for old, low elevation, mixedwood near waterways and bodies. However, once spatial dependencies were accounted for through autologistic regression, occurrence was positively associated with low elevation and the autocovariate, while larch was avoided.

This project has confirmed that northern pygmy and barred owls are widely distributed and occur at low densities throughout the study area. In doing so, we have provided the first population density estimate for northern pygmy owls in Alberta, and refined barred owl estimates based on new data and the use of *distance sampling*. Additionally, the use of habitat selection models and geographical information systems will now enable managers to focus future survey efforts, set habitat goals and evaluate the effects of management decisions on current and future habitat availability.

1.0 INTRODUCTION

Northern pygmy (*Glaucidium gnoma*, NPOW) and barred (*Strix varia*, BAOW) owls are ranked as 'sensitive' by the province of Alberta, which means they are not believed to be at immediate risk of extirpation or extinction but may require special attention or protection to prevent them from becoming at risk (CESCC 2001). For both species, this designation is largely the result of small population sizes and perceived threats from industrial activity. However, because few studies have been conducted on northern pygmy and barred owls directly, little is known about their provincial distribution and ecology. Traditional avian census techniques and monitoring programs are designed to reveal trends of more commonly encountered species. As a result, species such as owls, which are widely dispersed and occur in low densities, are often overlooked (Downes et al. 1999, Takats et al. 2001). Therefore, trend and abundance estimates for both these owls are lacking if existent at all (Sauer et al. 1996, Sauer et al. 2001).

The barred owl is generally considered to be an indicator of old intact stands as it is known to require large natural cavities for nesting (Takats 1998, Mazur and James 2000), and avoid stand openings due to the risk of predation by great horned owls (*Bubo virginianus*: Laidig and Dobkin 1995). Although these general habitat preferences are well defined, species' habitat associations vary widely from region to region and no studies have quantified these associations for the eastern slopes of Alberta. Meanwhile, the northern pygmy owl is believed to be a habitat and food generalist (Giese 2000) with a preference for habitat edges (Holt and Petersen 2000). However, like the barred owl, it is also an obligate cavity nester. Therefore, they must rely on natural cavities or those produced by other species, for nesting sites (Holt and Petersen 2000).

Cavity nesters are of primary interest to the forestry industry because cavities tend to form in older trees. Most forest harvesting programs aim to harvest stands before cavities occur, when fibre quality is at its prime. Without a firm understanding of species habitat requirements, this practice may lead to the lowering of snag densities and loss of forest age and structure classes required by obligate cavity nesters (Drapeau et al. 2002).

Specific objectives of this project were to:

- *Determine distribution and abundance of northern pygmy and barred owls along the eastern slopes of the Alberta Rocky Mountains.*
- *Examine the influence of biophysical factors on the distribution of northern pygmy and barred owls within the same region.*

2.0 STUDY AREA

Surveys for both species were conducted almost entirely within the southern half of the Alberta Foothills Natural Region (AEP 1994, ANHIC 2002). The entire study area extends from just north of Hinton and Edson, southeast along the edge of the Rocky Mountains to just south of Calgary, covering an area of nearly 37 000 km^2 (NPOW: 28 500 km^2, BAOW: 28 000 km^2, Figure 1). This area contains approximately 50% of all

historical records for northern pygmy owls in Alberta (Hannah 1999), and 20% of known barred owl range in the province (Olsen 2003).

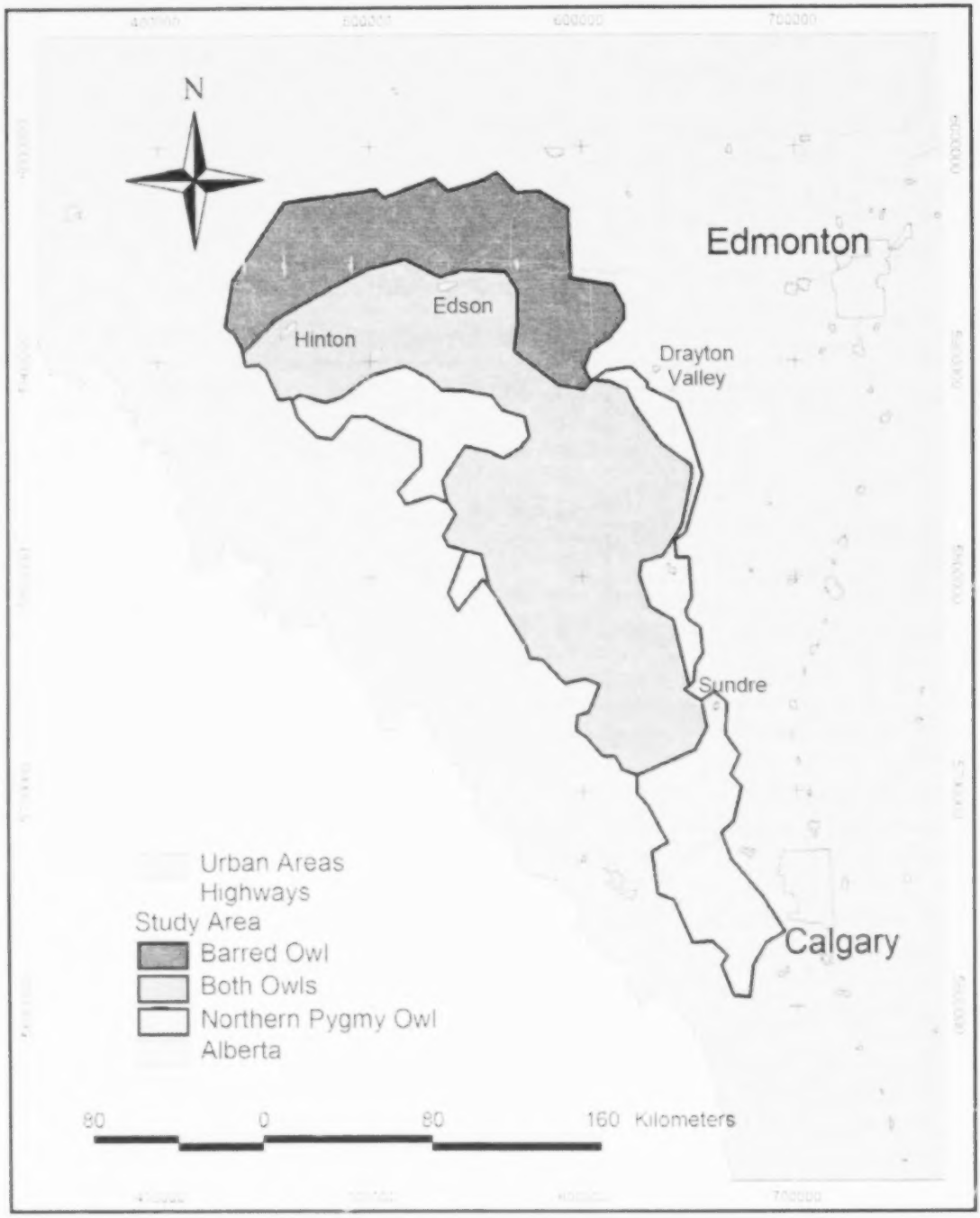

FIGURE 1 — PROJECT STUDY AREA.

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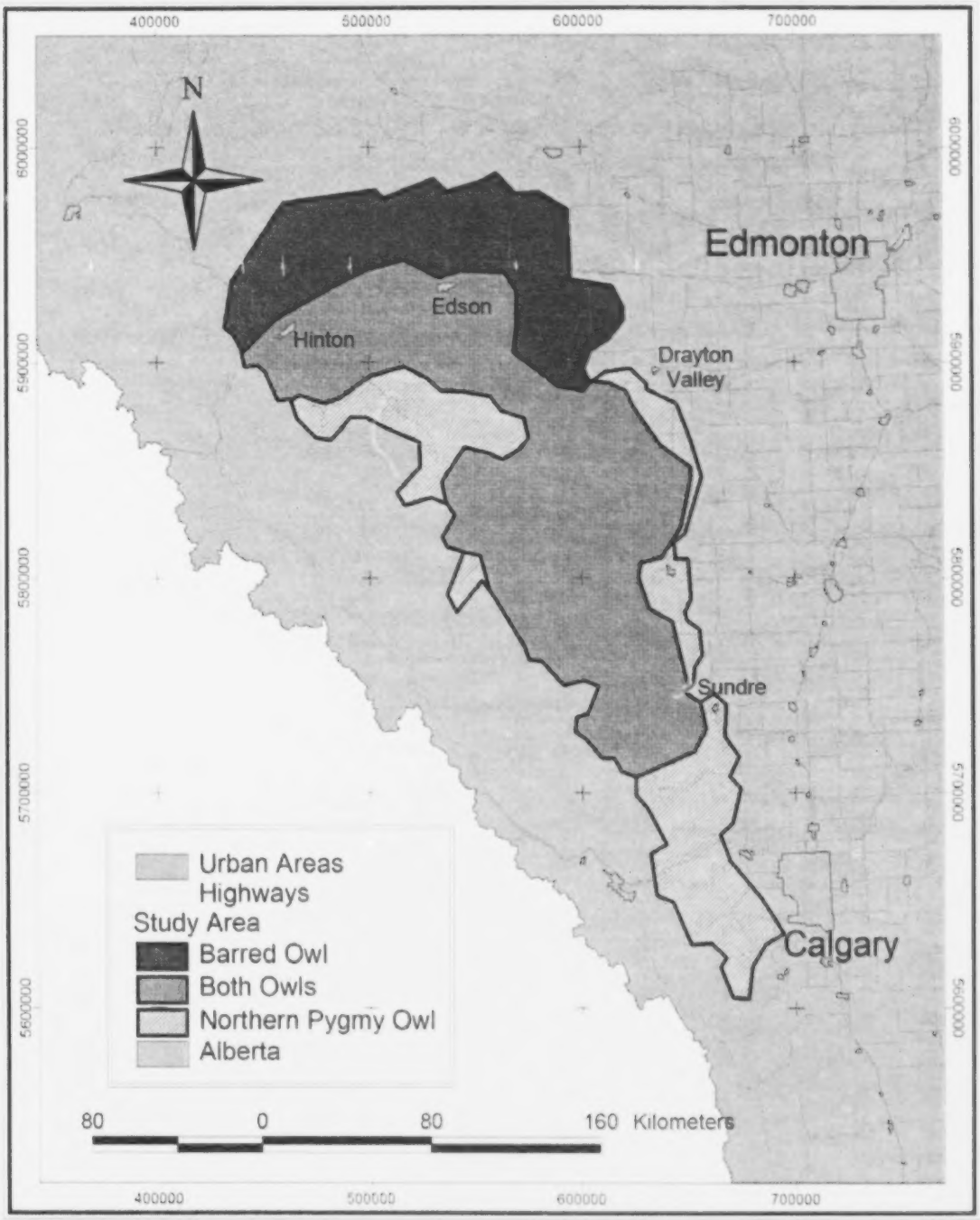


FIGURE 1 PROJECT STUDY AREA.

3.0 METHODS

3.1 Broadcast Surveys and Distribution

In 2001, diurnal broadcast surveys were conducted at 1.6 km intervals along accessible roads, to locate northern pygmy owls. Broadcast surveys consisted of playing conspecific breeding calls, to elicit an owl response (Takats et al. 2001) and have been shown to increase detection rates of numerous owl species (Debus 1995, Loyn et al. 2001). Nocturnal broadcast surveys for barred owls were conducted over three years (1999-2001) and involved four separate projects. Amalgamation of data was conducted to increase the observed sample size and make the barred owl study area comparable to that of the northern pygmy owl.

Surveys for both species were confined to roads in order to increase survey efficiency and sample size at the cost of obtaining randomness. Surveys were timed to coincide with pair initiation activities early in the breeding season and followed the general methodology later endorsed by Takats et al. (2001). Although all surveys used playbacks, there were differences in the spacing, timing and duration of playback surveys (Table 1).

TABLE 1 NORTHERN PYGMY AND BARRED OWL SURVEY SAMPLING PROTOCOL.

Study Area (year)	Sundre (2001)	Drayton Valley (1999)	Hinton (1999, 2000)	Edson (2000)	Sundre (2001)
Species	NPOW	BAOW	BAOW	BAOW	BAOW
Number of Visits	1	2	2	3	1
Survey Type (# unique pts)	Continuous transect (1532 pts)	8 transects of 12 points each (96 pts)	10 transects of 10 points each (100 pts)	10 transects of 12 points each (120 pts)	Continuous transect (211 pts)
Point Spacing	1.6 km	1.6 km	1.6 km	1.6 km	2.5 km
Survey Timing	early March – early May	mid February – late April	mid March – late April	early March – mid April	mid April – early May
Initial Period	2 min listen	2 min listen	2 min listen	2 min listen	2 min listen
Call Playback/ Listen	90 sec	20 sec/2 min repeat 3 times	20 sec/1 min repeat 6 times	20 sec/1 min repeat 3 times	120 sec
Final Period	4 min listen	5 min listen	5 min listen	3 min listen	4 min listen
Include Playback of Other Species	No	Yes	No	Yes	No
Playback Audible to Human at X meters	400 m	600 m	?	600 m	600 m

For all surveys, when an owl responded its direction and estimated initial response distance were recorded. Additionally, for northern pygmy and some barred owl sites, the type of response was also recorded as call, call and approach, or silent approach. Other

environmental data recorded, but varying slightly between the four barred owl surveys, included: survey date, time, temperature, cloud cover, sun/moon obscurity, wind speed (Beaufort scale), precipitation, topography (terrain roughness), road type, number of vehicles and noise level. Drayton Valley site information, for locations where owls were not recorded, was unavailable for this analysis.

All 2001 survey locations were recorded on initial visit with Garmin 12XL handheld Global Positioning System units in UTM format using the NAD83 datum. Others sites were initially noted on 1:50 000 scale provincial road access maps, and later recorded with portable GPS units.

3.2 Density Estimates

Density estimates for the northern pygmy and barred owl study areas were produced using *Distance 4.0* (Thomas et al. 2002a). *Distance* is a Windows-based computer package that allows the user to analyze distance-sampling surveys of wildlife populations. It can be used with point or line transect data that contains 'distance-to' records for each observation. Density estimates were completed using all acquired owl data sets. Additionally, five northern pygmy owl observations (six birds) were added to the northern pygmy owl database to aid in developing a more robust detection function. These birds were removed for calculation of density estimates.

Analysis started with examination of distance data histograms (detection frequency versus distance), to screen for evasive movement of owls and outliers (Buckland et al. 1993). Initial *detection functions* were then fit to the owl data sets. Fitted functions serve to estimate the proportion of targeted species missed by the survey (Thomas et al. 2002b), by describing the probability of detecting an object given that it is at distance x from the point or transect (Buckland et al. 1993). Data sets for both owls were truncated (0-75m) and grouped into six equal classes (NPOW: 76-850m, BAOW: 76-1250m), in order to reduce the number of model adjustment parameters, lessen the negative impact of evasive movement (Buckland et al. 1993) and increase accuracy and consistency among and within observers (Rosenstock et al. 2002). Data were also considered for post-stratification, because although variation in detection probability is not affected by pooling, variation in density estimates is. Therefore, post-stratification can have the effect of improving accuracy and reducing density estimate biases (Rosenstock et al. 2002).

Four candidate models were fit using the following key function and series combinations: hazard / cosine, uniform / simple, uniform / cosine, and half-normal / cosine. The model representing the most appropriate detection function was chosen by considering the following (Buckland et al. 1993): 1) model Akaike Information Criteria corrected for low sample sizes (AICc), 2) model fit close to zero, 3) Goodness-of-fit (GOF) of each detection function, 4) number of model parameters, and 5) reasonable and intuitive estimations of effective detection radius (EDR). EDR is the radial distance beyond which as many owls are detected, as are missed within (Thomas et al. 2002b). EDR is used to determine the amount of area effectively surveyed at each point, this in turn is used to determine the total area surveyed. Chosen models were then used together with bootstrapping to obtain estimates of density (Buckland et al. 1993).

3.3 Biophysical Factors

ArcView 3.2 and its *Spatial Analyst* extension (ESRI Inc. 1999) were used to extract biophysical characteristics present at all survey locations and at random sites (see Model Extrapolation section) within the study area. For each species, biophysical factors were identified at two spatial scales. These scales represent the owls' minimum and maximum home range estimates as determined from available literature (NPOW: 75 and 300 ha, BAOW: 100 and 400 ha, Kavanagh and Bamkin 1995, Loyn et al. 2001). When owls were present, analysis plots were centred on owl response locations. When they were absent, analysis plots were centred on random points situated within 600 m or 800 m of the survey point for northern pygmy and barred owls, respectively.

Biophysical characteristics were chosen based on perceived and/or documented importance to northern pygmy and barred owls (Table 2). Similarly biophysical variables were limited to those characteristics available (directly or inferred) from Alberta Vegetation Inventory (AVI), road/cutline networks, waterbody/river layers and Digital Elevation Model (DEM) coverages. Fragmentation indices were calculated with *Patch Analyst 2.2* (Elkie et al. 1999), and a *Grid Surface Areas* extension was used to provide terrain variability measures (Jenness 2002).

All biophysical variables, other than fragmentation indices, derived from AVI coverage were expressed as: 1) a variable representing the original percent value (0-100%) and as 2) a grouped variable, with the following grouping classes 0-5, 6-15, 16-25, ... 86-95, and 96-100 percent. For some variables grouping helped even the observed distribution.

3.4 Habitat Selection Models

Model Creation

Model creation began with logistic regression, and was conducted in *SPSS 11.0.1* (SPSS Inc. 2001) using forward stepwise variable selection (α=0.10) and a test for backward elimination (α=0.15). Manual constraints were employed to help reduce the number of variables and produce parsimonious models with biologically relevant predictors.

Four models were created for each species. The first two were developed from all biophysical variables relevant to the spatial scale of interest (i.e. minimum or maximum home range). The third considered all biophysical variables at both spatial scales and the final considered all biophysical variables at both spatial scales that exhibited significant univariate difference between 'use' and 'non-use' survey sites. Data were first screened for logically related variables, and then highly correlated pairs of independent variables using Spearman correlation coefficients ($r \geq 0.65$, Loyn et al. 2001).

Model selection was based upon corrected Akaike Information Criterion (AICc) for small sample sizes, a preference for a minimum number of predictors, variability accounted for by the model (Nagelkerke R^2, Peng et al. 2002) and predictive power (Kunkel and Pletscher 2000). Predictive power was assessed with classification tables and Receiver Operating Characteristics (ROC) plots. Classification tables display the

TABLE 2 BIOPHYSICAL FACTORS ISOLATED FOR ANALYSIS WITH NORTHERN PYGMY AND BARRED OWL SURVEY LOCATION DATA.

Source	Category	Biophysical Variable	Code
1:30 000 Alberta Provincial Government DEMs	Terrain	Surface area (ha)	SURFA
		Surface area ratio (ha)	SURFR
		Mean Elevation (m)	ELEV
		Mean Slope (degrees)	SLP
		Mean Aspect (degrees)	ASP
Alberta Vegetation Inventory (AVI)	Moisture Regime	Mesic	MOM
		Wet	MOW
		Dry	MOD
		Aquatic	MOA
		Unknown	MOU
Alberta Vegetation Inventory (AVI)	Crown Closure	A density (6-30%)	CCA
		B density (31-50%)	CCB
		C density (51-70%)	CCC
		D density (71-100%)	CCD
Alberta Vegetation Inventory (AVI)	Overstory Species Composition	trembling aspen (*Populus tremuloides*)	AW
		pine (*Pinus spp.*)	P
		balsam poplar (*Populus balsamifera*)	PB
		white spruce (*Picea glauca*)	SW
		black spruce (*Picea mariana*)	SB
		Engelmann spruce (*Picea englemannii*)	SE
		larch (*Larix laricina*)	LT
		sub-alpine fir (*Abies lasiocarpa*)	FA
		balsam fir (*Abies balsamea*)	FB
		paper birch (*Betula papyrifera*)	BW
Alberta Vegetation Inventory (AVI)	Forest Age Composition	Age 0-20 years	AG20
		Age 21-40 years	AG40
		Age 41-60 years	AG60
		Age 61-80 years	AG80
		Age 81-100years	AG100
		Age 101-120 years	AG120
		Age 121-140 years	AG140
		Age 141-160 years	AG160
		Age >160 years	AG161
Alberta Vegetation Inventory (AVI)	Forest Height Composition	Height 0 m	HT0
		Height 1-5 m	HT5
		Height 6-10 m	HT10
		Height 11-15 m	HT15
		Height 16-20 m	HT20
		Height 21-25 m	HT25
		Height 26-30 m	HT30
		Height >30 m	HT31
Alberta Vegetation Inventory	Forest Canopy Structure	Multi-Layered-stands with 2 or more distinct visible layers	STRM
		Complex-multiple layers limited to SB, LT, FB and old SW	STRC
		Horizontal-homo. stands within different homo. stands	STRH
Alberta Vegetation Inventory	Alternative Structure	Water	WATER
		Non-forested	NFOR
		Non-vegetated	NVEG
Alberta Vegetation Inventory (AVI)	Fragmentation Indices	Number of Patches	NUMP
		Mean Patch Size	MPS
		Total Edge	TE
		Edge Density	ED
		Mean Patch Edge	MPE
		Mean Shape Index	MSI
		Area Weighted Mean Shape Index	AWMSI
		Mean Patch Area Ratio	MPAR
		Mean Patch Fractal Dimension	MPFD
		Area Weighted Mean Patch Fractal Dimension	AWMPFD
		Median Patch Size	MEDPS
Linear Access Waterbodies	Linear Densities	Road Density (m/ha)	RDDEN
		Cutline Density (m/ha)	CUT
		Hydroline Density (m/ha)	HYDRO

Note: All variables were extracted at two spatial scales for each species. NPOW: s = 75 ha, l = 300 ha. BAOW: s = 100 ha, l = 400 ha. All grouped variables are identified by the addition of a 'g'. All lengths are in meters and areas in hectares.

number of correct and incorrect predictions made for the current data set, using cutoff values of 0.08 for northern pygmy and 0.28 for barred owls. Probabilities greater than the cutoff values identify sites where owls are predicted to occur. Cutoff values were chosen due to the high dispersion of these species, and because they approximate the response proportions of data used to develop the models (Carroll et al. 1999, Loyn et al. 2001). ROC plots assess model success across a full range of dichotomies and not just at a single cutoff point. The area under the ROC curve (AUC) is a single measure of overall fit, ranging from 0.5 for chance performance, to 1.0 for a perfect fit (Osborne et al. 2001).

Final logistic regression models for each species were then used as starting points for fitting autologistic models. Logistic regression models require that the response variable is independent. When independence is violated due to spatial autocorrelation, autologistic regression is more appropriate. Autologistic models account for spatial autocorrelation through the addition of an autocovariance variable. Autocovariate variables were calculated for a number of different neighbourhood sizes. Then, model AICc, predictive power and significance of predictor variables were used to determine which neighbourhood size produced the most parsimonious autologistic model. Autocovariates were calculated as:

$$autocov_i = \frac{\sum_{j=1}^{n} w_{ij} y_j}{\sum_{j=1}^{n} w_{ij}}$$

With *wij* being the inverse of the Euclidean distance between stops *i* and *j*, while *y* represents the response variable, 0 if owls were absent and 1 if they were present (Augustin et al. 1996). Calculation of autocovariates and creation of autologistic models was completed using *R 1.7.1*, a free statistical data analysis program, and its' *SPDEP*, *DESIGN* and *GLM* packages (Ihaka and Gentleman 1996). Z values for logistic and autologistic regression model residuals were then compared across all spatial lags, using *Rook's Case 0.96* (Sawada 1999).

Model Extrapolation

In an attempt to determine if extrapolation of model outputs could be made to the entire study area or if they should be limited to certain regions, the means and ranges of variables used to create the final logistic and autologistic regression models were compared to those from random sites throughout the study area. Approximately 550 sites, selected in a stratified random manner were used for this analysis. Random sites were selected in a quantity large enough to provide for: near equal sample sizes between visited and random sites, stable variable variances, and feasible computation times (Stevens 2002, Appendix 1). The percentage of random points exceeding the range observed at survey sites was also determined.

3.5 Mapping Probability Surfaces

Biophysical attributes identified by habitat selection models were prepared in order to visually map the probability surfaces for northern pygmy and barred owls within a

portion of the study area. Habitat variables were identified from AVI data using the *ArcView 3.2 Query Builder* and converted into unique raster data layers with a cell resolution of 100 m. Grid cells meeting the selection criteria (e.g. Height 25-30 m) were given a value of 100 (i.e. percent) and the remainder were given a value of zero. All data layers (i.e. habitat attributes, elevation, slope, road density) were then exported into *Surfer 8.02* (Golden Software Inc. 2002), where a circular moving average filter representing the analysis scale of interest (i.e. min or max home range size) was applied. The moving average function assigns a mean value to the input cell, based on the values of adjacent cells within the range of the moving window (Hirzel et al. 2001), thereby creating a data layer where each cell represents the value of an attribute at the spatial scale of interest (e.g. percent aspen at the maximum home range scale). These layers were then returned to *ArcView*, where they were combined as specified by the final model formula, using the *Map Calculator* function. Visual outputs were restricted to a central portion of the study area (Sunpine FMA) due to the excessive amount of computer time required to compute the necessary model layers using this technique.

Mapping of autologistic models also requires the calculation of an autocovariance term, based on observed species 'use' or 'non-use' within a defined neighbourhood. Autocovariates were calculated for the logistic regression probability surfaces (Osborne et al. 2001) and the results were combined with biophysical variables, as indicated by the autologistic regression models, to create the first autologistic regression probability surfaces. This procedure was then repeated on the new probability surfaces, until the fitted probabilities converged. Using a similar process Augustin et al. (1998) found that convergence of fitted probabilities occurred at about the fifth iteration and that even probability maps with one autologistic iteration performed better than logistic regression models. An inverse Euclidean distance filter was used in *Surfer 8.02*, to create the autocovariate data layers from probability outputs.

4.0 RESULTS

4.1 Broadcast Surveys and Distribution

During the eight weeks of surveying for northern pygmy owls in 2001, 1532 site visits were made within the study area (Figure 2). Forty-eight responses were recorded at 42 sites representing 40 individual northern pygmy owls. The majority of these sites were visited only once. However, six of the 42 sites with owls were visited twice. Owls responded on both visits at only two sites. Two additional sites were visited on three occasions. At one an owl responded on each visit, while at the other an owl responded two of three times. In total over 2500 km of road were surveyed for northern pygmy owls. With 40 birds responding, a basic linear abundance of 0.016 birds/km was estimated.

Of the environmental variables measured, only terrain roughness and wind speed exhibited a discernable and consistent effect on northern pygmy owl detection rates. Frequency of response increased with terrain roughness, and decreased with a rise in wind intensity. For owls that responded to call playbacks, the majority (70%) responded

during the final four minute listening period and call responses were almost evenly split between 'call' (43%) and 'call and approach' (57%, Table 3).

TABLE 3 NORTHERN PYGMY OWL RESPONSE DETECTION INTERVALS AND RESPONSE

Response Interval	**Before Playback (2min)**	**During Playback (2min)**	**After Playback (4min)**	**Total**
Number	6 (13%)	8 (17%)	33 (70%)	47
Response Action	**Call**	**Call and Approach**	**Approach (No call)**	
Number	20 (43%)	26 (57%)	0 (0%)	46

During the barred owl surveys (1999-2001) over 1150 visits, at 527 unique sites, were made within the study area (Figure 3). The Hinton survey was the only one conducted during multiple years (1999-2000), with a similar number of responses, response sites and unique birds obtained in both years. Summarizing the entire study area results, using Hinton 2000 data for that region, 63 barred owl responses were recorded at 54 sites, representing 45 unique individuals. The majority of sites were visited at least twice (316 of 527 unique sites). Owls were observed calling on two occasions at only five sites. At an additional five sites, owls were observed calling on one visit and recorded in an adjacent site on the next. A total of over 1030 km of road were surveyed for barred owls. With 45 birds responding, a basic linear abundance of 0.044 birds/km was estimated.

In general, barred owl detection rates decreased as wind speed and precipitation type increased in intensity. Survey results also suggest that late-March, followed by early-April, are the most effective times of the spring to survey for barred owls in Alberta. Response to call playbacks ranged from 57 to 100 %, with between 7 and 42 % of responding birds approaching the observer (Table 4).

TABLE 4 BARRED OWL RESPONSE DETECTION INTERVALS AND RESPONSE ACTION, 1999-2001.

Response Interval	**Drayton Valley (1999)**	**Hinton (1999/2000)**	**Edson (2000)**	**Sundre (2001)**
Before Playback	0	6 / 1	5	5
Other Species Playback	2	NA	6	NA
After 1st BAOW	0	2 / 5	0	2
After 2nd BAOW	7	2 / 5	4	
After 3rd BAOW	3	4 / 0	5	
After All Playbacks	5	0 / 0	2	5
Response Action				
Call	NA	13 / 9	NA	7
Call and Approach	NA	1 / 2	NA	5

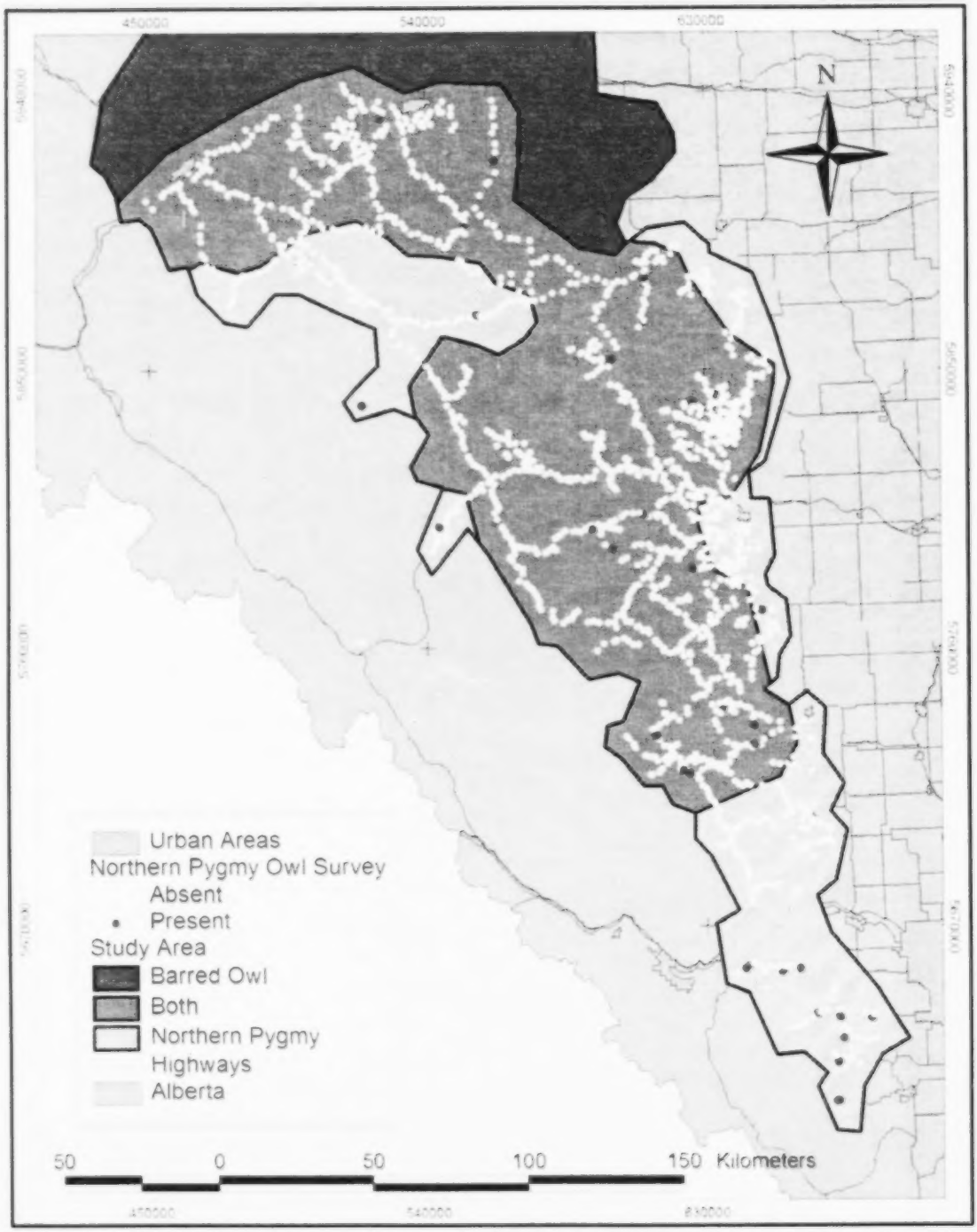


FIGURE 2 DISTRIBUTION OF NORTHERN PYGMY OWL SURVEY LOCATIONS IN THE FOOTHILLS OF WEST-CENTRAL ALBERTA, 2001.

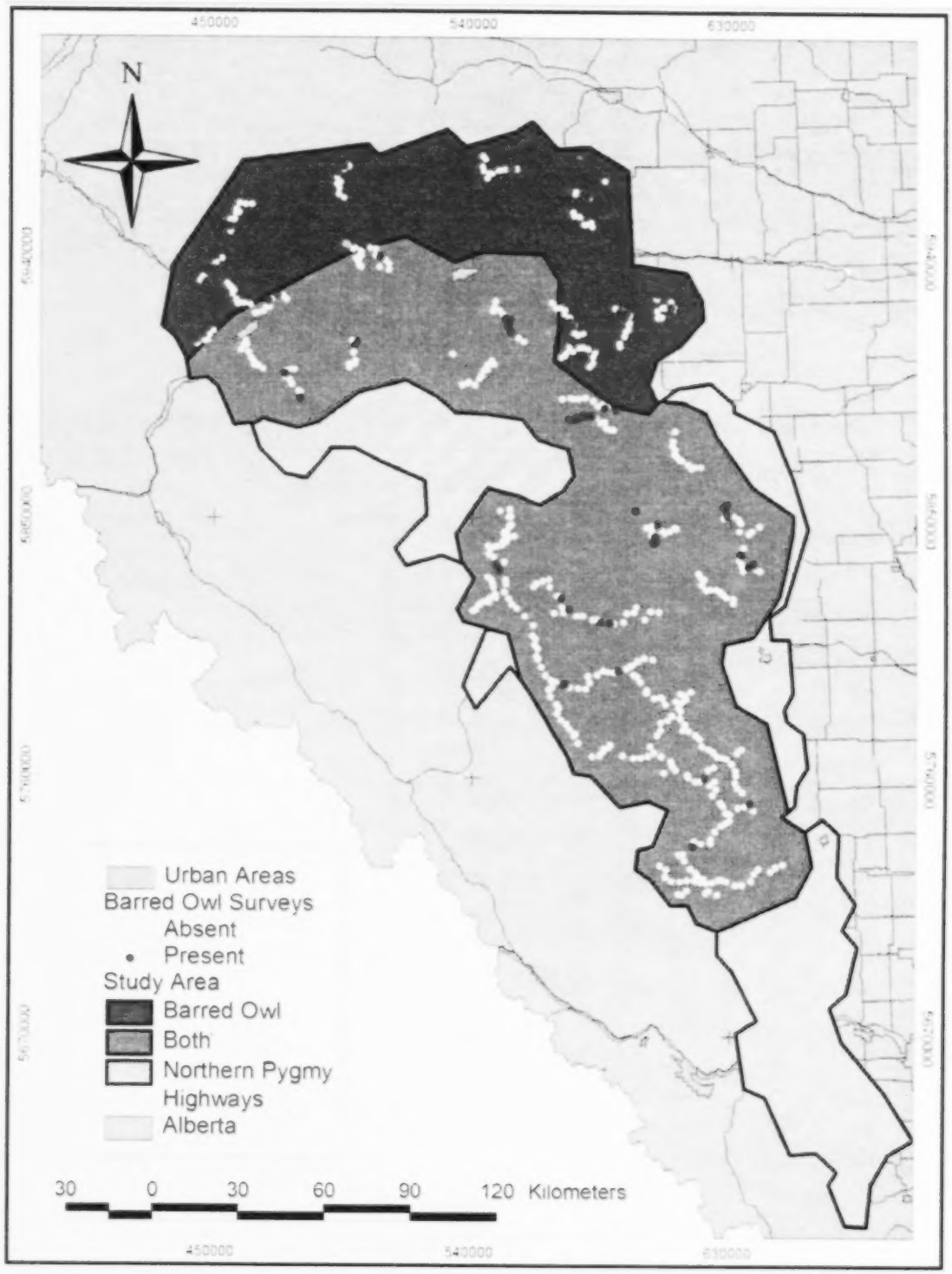


FIGURE 3 DISTRIBUTION OF BARRED OWL SURVEY LOCATIONS IN THE FOOTHILLS OF WEST-CENTRAL ALBERTA, 1999-2001.

4.2 Density Estimates

Models using half-normal / cosine detection functions were identified as being most parsimonious for both northern pygmy and barred owl models (Piorecky 2003). These models had the lowest AICc, best goodness-of-fit and realistic EDRs. Density and abundance estimates for northern pygmy and barred owls were obtained from the half-normal/cosine models, using bootstrapping to improve measures of accuracy. Barred owl data were also subject to post-stratification by project, to help account for additional variation between the various surveys. This analysis defines northern pygmy and barred owl density estimates of 0.048 and 0.025 birds/km^2 respectively (Table 5). Bootstrapped coefficients of variance (CVb) are estimated at 55.8 and 30.7 percent. Both values are very high, resulting in wide ranging density estimates. The 95% confidence interval for the northern pygmy owl density estimate is 0.017-0.135 birds/km^2, while that of the barred owl is 0.013-0.047 birds/km^2. This represents a difference of a factor of 8 and 3.5 for each species, respectively.

TABLE 5 NORTHERN PYGMY AND BARRED OWL DENSITY AND POPULATION SIZE ESTIMATES, CALCULATED USING DISTANCE SAMPLING.

	# Observations	# Sample	Density (#/km2)	D CV	D CVb	Number Indiv. (#/28,150 km^2)	N CV	N CVb	# Bootstrap Samples	Probability Of Detection	P CV
NPOW	30	1523	0.048	27.7	55.8	*1346	27.7	55.8	500	0.21	21.0
BAOW	34	928	0.025	26.6	30.7	*706	26.6	30.7	500	0.30	20.8

* These estimates assume that owl densities found can be applied to the entire NPOW and BAOW study areas.

4.3 Habitat Selection Models

Model Creation

Because of the nature of our data (i.e. highly autocorrelated variables), autologistic regression was deemed the most appropriate form of analysis (Klute et al. 2002), and therefore only autologistic models results are presented. For a more detailed comparison of logistic versus autologistic regression results see Piorecky (2003).

The best models were those that considered all biophysical variables at both spatial scales and exhibited significant univariate difference between "use" and "non-use" survey sites. Neighbourhood sizes of 8500 and 4650 m radii were used to produce the most parsimonious models for northern pygmy and barred owls respectively.

The best northern pygmy owl model contained 10 biophysical variables, a spatial autocovariate and a constant, while the barred owl model was limited to two biophysical variables, a spatial autocovariate and a constant. Equations for the final autologistic regression models are as follows.

Northern Pygmy Owl

(Z) = -6.25 + 0.049(HT30:s) + 0.275(SLP:s) + 0.029(AW:l) – 0.075(CCB:lg) + 0.025(HT25:s) + 0.043(AG161:lg) + 0.051(RDDEN:s) – 0.025(AG80:s) – 0.066(HT10:sg) + 0.036(MOW:lg) + 4.344(AUTOCOV)

Barred Owl

(Z) = 1.295 – 0.003(ELEV:s) – 0.093(LT:l) + 4.005(AUTOCOV)

Probability of occurrence for each species was calculated by inserting the appropriated Z value into the equation *Probability of Use* = $e^Z / (1 + e^Z)$. Model variable descriptions, coefficients (β), standard errors (SE), significance (α), odds ratios (Exp (β)) and 90% odds ratio intervals are all reported in Table 6.

TABLE 6 FINAL AUTOLOGISTIC REGRESSION MODEL VARIABLES FOR NORTHERN PYGMY AND BARRED OWLS.

Variables	Description	β	SE	α	Exp (β)	Lower 90% CI	Upper 90% CI
		Northern Pygmy Owl					
HT30:s	% Height 26-30 m	0.049	0.020	0.015	1.050	1.016	1.085
SLP:s	Mean Slope (degrees)	0.275	0.064	0.000	1.317	1.185	1.464
AW:l	% Aspen	0.029	0.013	0.035	1.029	1.006	1.053
CCB:lg	% Canopy Closure 31-50%	-0.075	0.023	0.001	0.927	0.892	0.964
HT25:s	% Height 21-25 m	0.025	0.009	0.004	1.026	1.011	1.040
AG161:lg	% Stand Age >160 y	0.043	0.020	0.034	1.044	1.010	1.080
RDDEN:s	Road Density (m/ha)	0.051	0.021	0.017	1.052	1.016	1.090
AG80:s	% Stand Age 61-80 y	-0.025	0.013	0.066	0.976	0.955	0.997
HT10:sg	% Height 6-10 m	-0.066	0.033	0.050	0.936	0.885	0.989
MOW:lg	% Moisture Regime Wet	0.036	0.019	0.055	1.037	1.005	1.070
AUTOCO	Spatial Response Covariate	4.344	0.845	0.000	76.98	19.17	309.1
C	Constant	-6.253	1.002	0.000	0.002		
		Barred Owl					
ELEV:s	Mean Elevation	-0.003	0.001	0.008	0.997	0.995	0.999
LT:l	% Larch	-0.093	0.042	0.026	0.912	0.851	0.976
AUTOCO	Spatial Response Covariate	4.005	0.472	0.000	54.89	25.25	119.3
C	Constant	1.295	1.430	0.365	3.649		

Note: s=minimum home range scale, l= maximum home range scale, g=grouped data

All model variables were significant at the $\alpha<0.05$ level, except for AG80 ($\alpha=0.066$), MOW ($\alpha=0.055$), HT10 ($\alpha=0.05$) and the barred owl constant ($\alpha=0.365$). All northern pygmy owl model variables resulted in an increase in probability of selection, except for CCB, AG80 and HT10. The variable with the greatest magnitude of effect was AUTOCOV, for which change in the observed variable affects the model output by 7698%. Thought of another way, the odds of a northern pygmy owl occurring at a given site are nearly 77 times greater if owls also occur at all neighbouring sites. Other variables in the pygmy owl model displayed relatively minor effect-magnitudes, ranging from 0.2 to 7.3%. Meanwhile for the barred owl model, half the variables decreased the probability of selection (ELEV, LT) and the other half increased probability of selection

(AUTOCOV, Constant). The greatest effect was exhibited once again by AUTOCOV at 5489%. The next largest effect magnitude was exhibited by the constant, at 365%. Finally, odds ratio confidence intervals did not span one for any of the model variables, indicating that these are all good predictors.

The northern pygmy owl autologistic regression model had an overall classification success of 84.8%, up 4.1% over the logistic regression model. It erroneously classified nine of 46 sites where owls were actually observed, as being absent. The barred owl model exhibited an overall classification success of 86.7%, up 16.4% over the logistic regression model, and misclassifying only 13 of the 74 sites where barred owls were observed. AUC values in ROC plots for both species increased in autologistic regression models (NPOW: 0.856 to 0.892, BAOW: 0.775 to 0.894).

Figures 4 and 5 show the Z values of Pearson residuals at various lag distances, for the logistic and autologistic regression models. For northern pygmy owls, significant autocorrelation of residuals exists for all smaller distance categories after fitting the logistic regression model. Alternatively, after fitting the autologistic regression model, no significant spatial autocorrelation is observed at any of the lag distances.

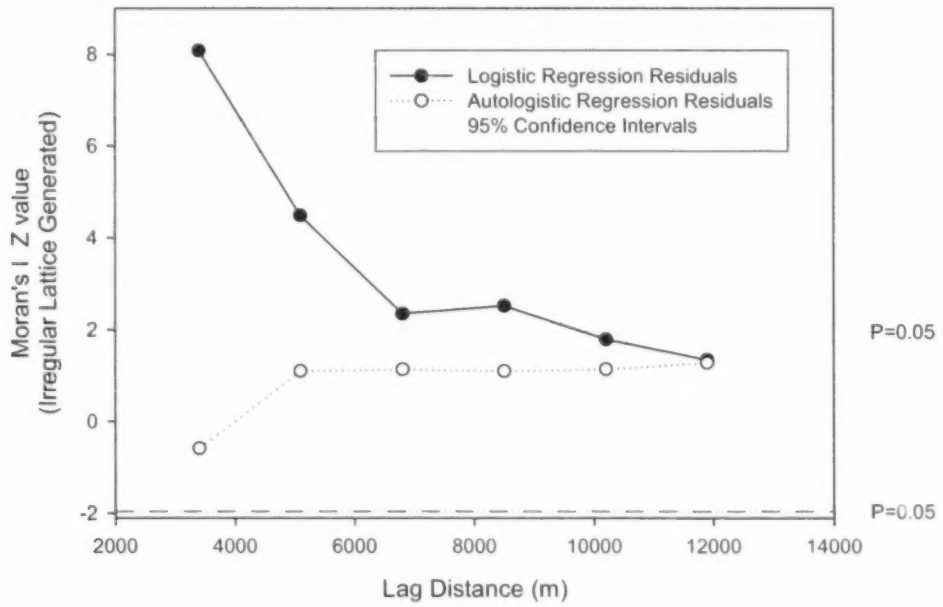


FIGURE 4 MORAN'S I Z VALUES FOR PEARSON RESIDUALS OF NORTHERN PYGMY OWL LOGISTIC AND AUTOLOGISTIC REGRESSION MODELS AT SIX SPATIAL LAGS.

Results from the barred owl models were similar. Significant autocorrelation of residuals were found in all logistic regression model spatial lags, while the autologistic model was found to completely remove significant spatial autocorrelation from model residuals.

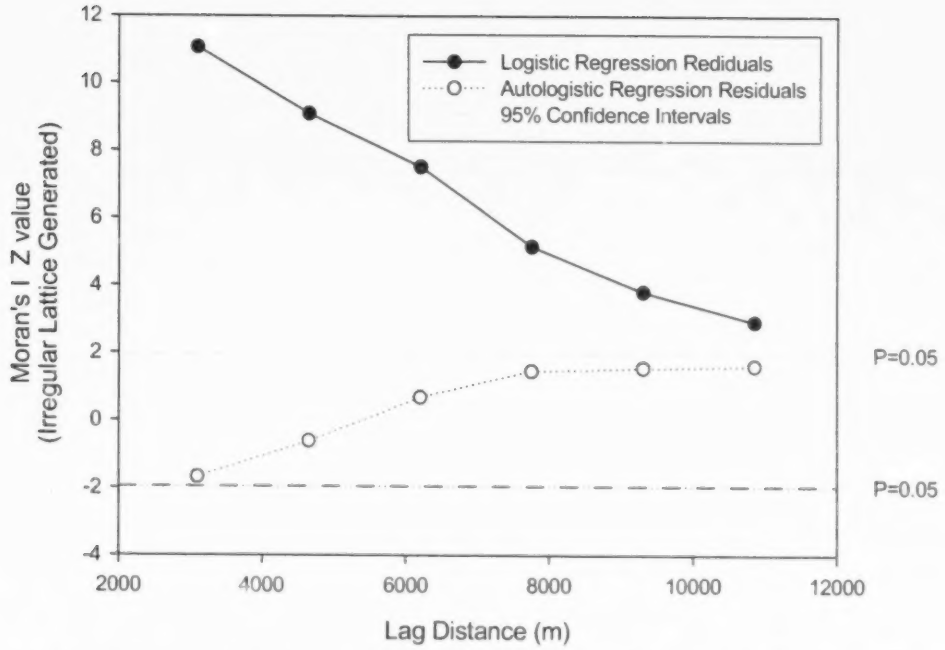


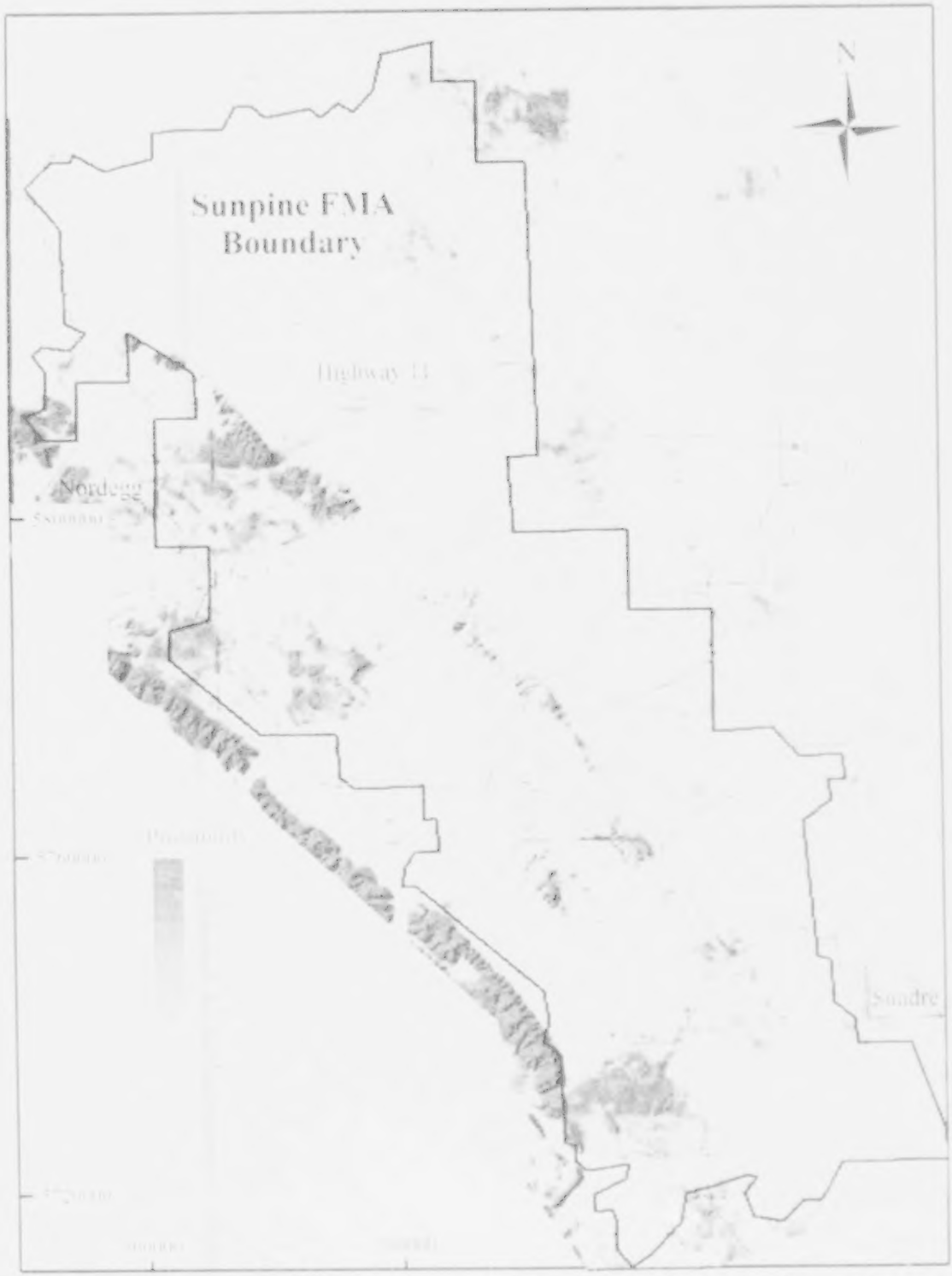
FIGURE 5 MORAN'S I Z VALUES FOR PEARSON RESIDUALS OF BARRED OWL LOGISTIC AND AUTOLOGISTIC REGRESSION MODELS AT SIX SPATIAL LAGS.

Model Extrapolation

Characteristics of model variables were compared at survey sites and random locations throughout the study area. Four of 10 northern pygmy owl model variables exhibited significant differences in means (AW, HT25, RDDEN and SLP), while none of two barred owl model variables were found to differ significantly. Variable minimums and maximums are also examined. For the most part, ranges of model variables observed at random sites were adequately covered by survey efforts; the one possible exception is elevation (ELEV). Over 2.5% of the random sites yielded mean elevation values of over 1782 m, which was the survey maximum.

4.4 Mapping Probability Surfaces

Numerous datasets, steps, manipulations and interim data layers were used to create the visual representations of owl probability of occurrence as determined by the autologistic regression habitat selection models (Figures 6 and 7). The northern pygmy owl probability map was produced with a probability cutoff of 0.08; all values above that are assumed to provide increasingly suitable habitat. Owls are not expected to occur at values lower than the cutoff. The barred owl map was produced with a probability cutoff of 0.28. These values were chosen based on the high dispersion of these species, and because they approximate the response proportions of data used to develop the models (Carroll et al. 1999, Loyn et al. 2001). Autologistic regression probability surfaces for both species were found to remain relatively stable by the fifth iteration.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Sunpine FMA
Boundary
Highway 13
Nordegg
Sundre

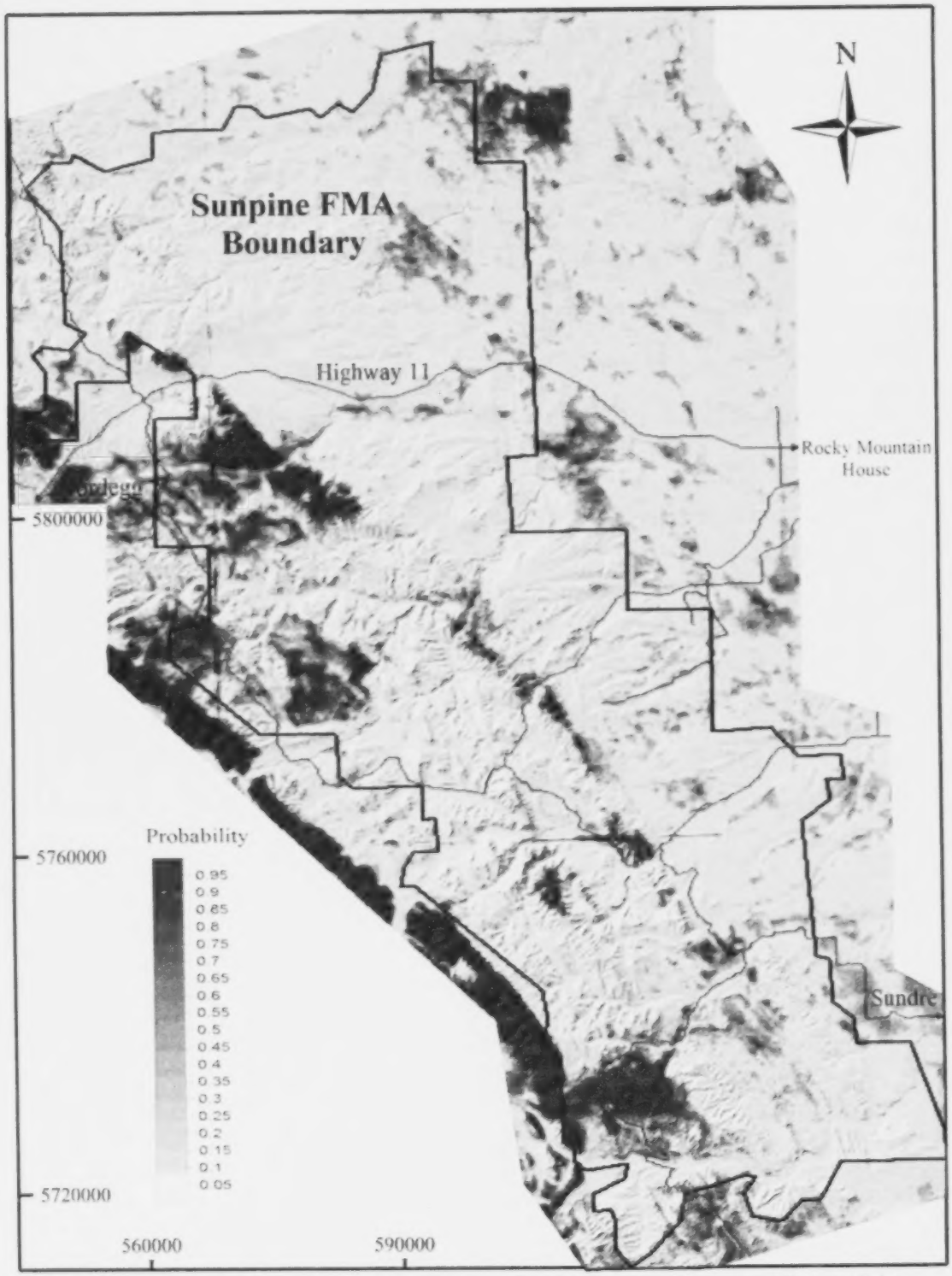

FIGURE 6 AUTOLOGISTIC REGRESSION PREDICTED PROBABILITY OF NORTHERN PYGMY OWL OCCURRENCE IN THE SUNPINE FMA AREA, 2003.

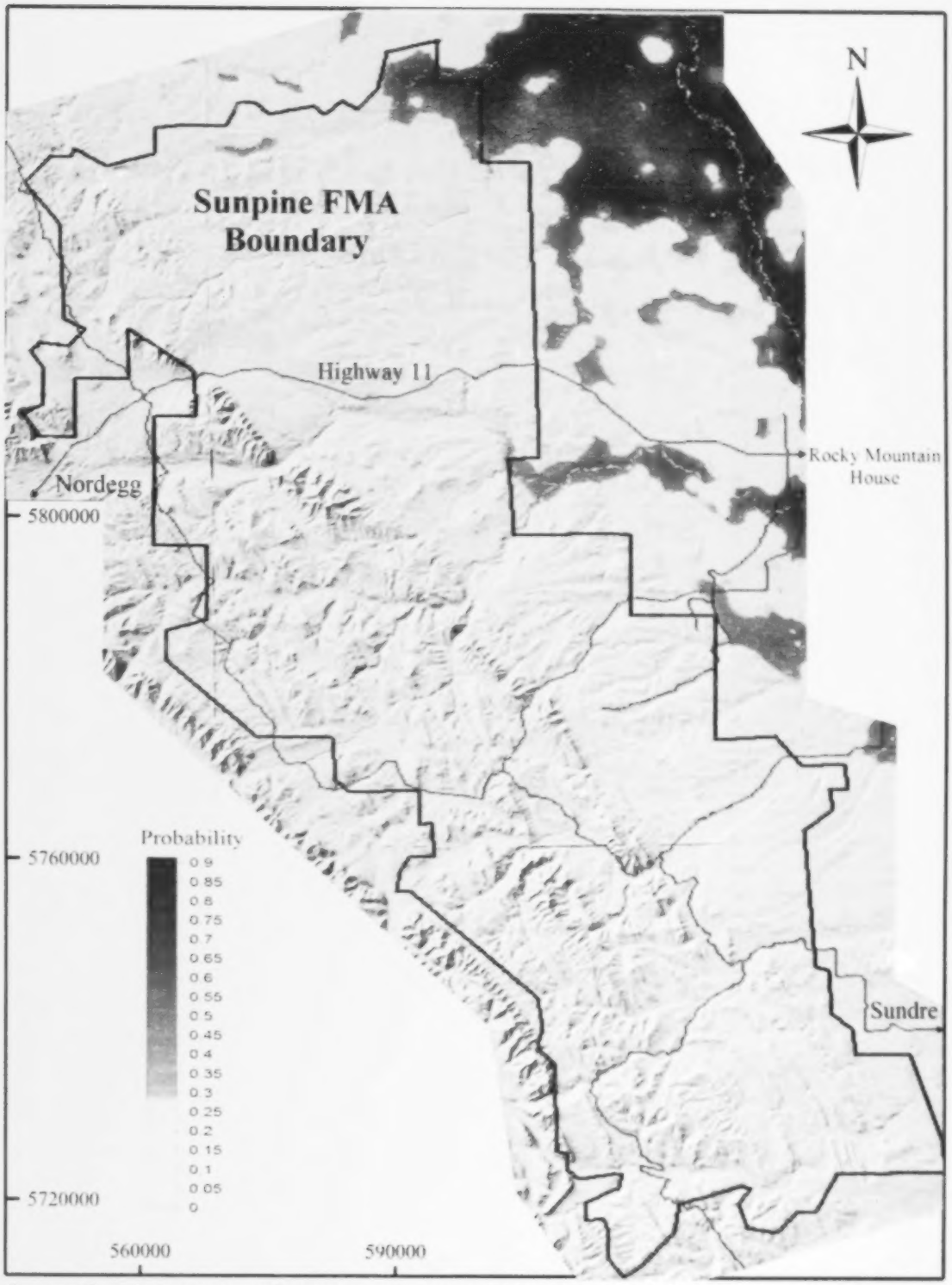

FIGURE 7 AUTOLOGISTIC REGRESSION PREDICTED PROBABILITY OF BARRED OWL OCCURRENCE IN THE SUNPINE FMA AREA, 2003.

5.0 DISCUSSION

5.1 Broadcast Surveys and Distribution

Broadcast surveys were successfully used to identify the influence of environmental factors, and determine the distribution of both owl species within the study area. Northern pygmy (87%) and barred owls (57-100%) responded readily to playbacks. While no similar studies on northern pygmy owls could be found, the B.C. Ministry of Sustainable Resource Management (2001) recommends surveying for northern pygmy owls with call playbacks. This project represents the first known attempt to specifically target northern pygmy owls with ***daytime*** surveys in Alberta, and has met with far greater success than any of its nocturnal survey counterparts (Takats 1998, Brown 1999, 2000). Meanwhile, in barred owls Francis and Bradstreet (1997) found the use of call playbacks increased detections by 50% in the first two minutes after playback, and Bosakowski (1987) documented a response rate of 82.4% to call playbacks. Response per unit effort however, was extremely low, especially for northern pygmy owls. This is likely a result of the pygmy owls low density and relatively small detection radius, stemming from its quiet call.

Many environmental factors were measured, however few showed any consistent association with owl encounter rates. Wind lowered observed owl detections (Debus 1995, Takats 1998), however it was unclear whether owl call rate or observer detection ability was influenced by wind (Debus 1995). Northern pygmy owl detection rates doubled with incremental increases in relative slope and complexity. While there is little in the literature that explains this finding, it could indicate a bias toward preferential detection of northern pygmy owls in rugged terrain, due to the owl's ability to obtain a higher calling perch and thus be detected from further away (i.e. lower sound attenuation). Alternatively, it could be related to habitat or foraging selection preferences, with more owls being detected simply because more are present. For the barred owl, precipitation type and was shown to influence detection rates, with similar results being observed by Takats (1998). Finally, the barred owl was shown to exhibit increased detection rates in late March and early April.

Prior to this project, distributional data for northern pygmy owls in Alberta came from opportunistic observations made by a variety of wildlife biologists and dedicated naturalists (Hannah 1999). In fact, it wasn't until 1971 that the first recorded nesting of the species in Alberta, was documented (Holroyd and Van Tighem 1983). Barred owls have recently received more attention in terms of research and monitoring (Takats 1998, Olsen 1999, Brown 1999, 2000). However, low densities and their nocturnal habits continue to limit our knowledge of distribution and abundance. This project revealed that both species are distributed in suitable habitat throughout the entire study areas in which they were surveyed.

5.2 Density Estimates

Most avian studies rely on procedures that use "point counts of bird detections as an index to abundance" (Rosenstock et al. 2002). An index is a ratio in which the actual population size to count ratio is unknown, and thus cannot be used to estimate density or population size (Bart and Earnst 2002). *Distance* adjusts for birds that are present but not detected, by creating a detection function based on the species initial distance of detection. *Distance* also

provides measures of accuracy, which helps eliminate erroneous conclusions regarding results and allows for meaningful comparison between studies.

Densities of 0.048 and 0.025 birds/km^2 were estimated for northern pygmy and barred owls respectively. This translates into population estimates of 1346 (95% CI: 478-3787) northern pygmy and 706 (95% CI: 374-1332) barred owls based on an area of 28 150 km^2. No other density estimates could be found for northern pygmy owls. After three years of recording barred owl observations, a density of 0.08 birds/km^2 was estimated for Calling Lake Alberta (B. Olsen pers. comm.), while a density of 0.05 birds/km^2 was estimated for the Hinton region (Takats 1998). Measures of accuracy are unavailable for these estimates.

Concerns over owl movement, small sample size and non-random distribution of survey sites were noted. The effect of call playbacks on owl movements is poorly understood. However, based on the barred owl results, it was approximated that 20% of owls moved toward the observer before responding. Additionally, grouping and truncation of survey data was used to nullify minor evasive movements occurring before detection and reduce the effects of distance estimation errors (Buckland et al. 1993, Nelson and Fancy 1999, Rosenstock et al. 2002). Sample size recommendations call for between 40 (Burnham et al. 1980) and 80 (Buckland et al. 1993) individuals as a practical minimum. Small sample sizes result in lower levels of accuracy. Meanwhile the limitation of surveys to roads raised questions about the ability to extrapolate density estimations to regions beyond the influence of roads. This project selected smaller, secondary and tertiary roads for transect routes, as these roads exhibit less pronounced differences between mean numbers of individuals (Hutto et al. 1995). Recognizing the limitations of these estimates, it must be stated that all density and abundance estimates produced herein are put forth as a basic range in which true density and population sizes for these difficult to measure species may exist. They are not robust at a fine scale, and should be used in the context of landscape management plans and initiatives. They are also however, some of the best data we have on northern pygmy and barred owl densities in western Alberta.

5.3 Habitat Selection Models

This study identified biophysical factors affecting the distribution of northern pygmy and barred owls along the eastern slopes of the Alberta Rocky Mountains and developed models to accurately predict their occurrence. While habitat supply is not a definitive indicator of population maintenance, it is one of the most important factors controlling population levels (Dempster 1998, Boyce and McDonald 1999). Once habitat selections are defined, "suitable habitat can be measured at low cost and with good reliability, replication and accuracy relative to actual population counts" (Dempster 1998). This tool will enable forest and wildlife managers to determine current areas of concentrated quality habitat as well as model the effect of various management options on future habitat quality and distribution.

It was shown that models incorporating multiple spatial scales outperformed single scale models, even within the confines of home range analysis, thereby emphasizing the importance of multiple scale analysis in habitat selection studies. Northern pygmy owls showed a preference for older, structurally diverse mixedwood habitats, with line-of-sight enhanced by increased edge and terrain roughness. Models for barred owls initially suggested a preference for old, low elevation, mixedwood near waterways and bodies.

However, once spatial dependencies were accounted for through autologistic regression, occurrence was positively associated with low elevation and the autocovariate, while larch was avoided. Although habitat configuration (e.g. number of patches, mean patch size, edge density, mean shape index, etc.) has been thought to potentially influence barred owl habitat selection (Olsen 1999), this project found no such association when all habitat characteristics were included in the analysis. However, habitat configuration may play a role when considering individually significant attributes (e.g. the number and size of patches 101-120 years old).

Habitat modelling is typically conducted using logistic regression. Logistic regression is a non-spatial analysis that requires independence of observations. When the response variable is autocorrelated, as is typically the case with species occurrences (Lichstein et al. 2002), the assumption of independence is often invalid, and the effects of covariates (e.g. environmental variables) that are themselves autocorrelated tend to be exaggerated (Grumpertz et al. 1997). Failure to account for positive spatial relationships results in lowered p-values of predictor variables, making it impossible to identify and remove weak predictors from the regression equation (Gutzwiller and Anderson 1986, Boyce and McDonald 1999). In this situation autologistic regression is more appropriate.

Autologistic models account for spatial autocorrelation through the addition of an autocovariance term. Autocovariance is a measure of local patterns of variability in species occurrence (Grumpertz et al. 2000), and quantifies the degree to which presence of a species at site X is affected by its presence in neighbouring sites or within a given spatial area (e.g. a radius of 750 m). Incorporating an autocovariance term allows us to weigh the effects of the different neighbourhood variables on survival while statistically controlling for the effect of spatial autocorrelation (Hubbell et al. 2001). By accounting for these spatial dependencies, autologistic models produced better fitting models (lower AICc) that more accurately reflect the role of predictor variables in influencing species occurrence (Augustin et al. 1996, Klute et al. 2002) and in the case of the barred owl, did so with fewer explanatory variables. Similarly, ROC plots yielded AUC values near 0.9 for both autologistic models, indicating very good discrimination (Pearce and Ferrier 2000).

6.0 MANAGEMENT AND RESEARCH RECOMMENDATIONS

When planning for the habitat needs of wildlife species it is important that they be managed over large spatial and temporal scales (Drapeau and Giroux 1999), and that cumulative impacts of major industrial activities (i.e. forestry and oil/gas) and natural disturbances (i.e. fire) be considered (Schneider 2001a, 2001b). The results of this research point to several specific management and research recommendations that could be incorporated into long-term planning for forest harvesting and other industrial activities occurring in northern pygmy and barred owl ranges.

Recommendation #1 – Maintain areas of tall, old mixedwood and deciduous forest within the landscape.

Our results suggest that both owl species preferentially select for tall, old stands with a deciduous component. The practice of establishing no-harvest zones around permanent

waterbodies and waterways is one approach to maintaining these attributes. However, it is important that habitat with these qualities also be maintained in other areas, to ensure the natural spatial distribution is not lost (Ohman and Eriksson 1998). This study did not address what the exact size and configuration of these habitats should be.

Recommendation #2 – Maintain live deciduous residual structure in harvest sites.
Retention of live deciduous clumps of trees after harvest will likely benefit northern pygmy owls by providing additional perching locations. Furthermore, these residual trees will increase the structural diversity of the replacement stand and provide future nest locations for numerous obligate cavity nesters (Drapeau et al. 2002). This study did not determine what residual retention rate would be most appropriate.

Recommendation #3 – Collect future wildlife survey data with distance estimates.
Distance sampling is preferable to conventional surveys because it allows for the creation of density estimates as opposed to indices of relative abundance. Distance methods are easily adapted to traditional line or point transect surveys, and have potential for use in the management of nearly all surveyed wildlife.

Recommendation #4 – Conduct northern pygmy owl surveys during daylight hours.
Survey protocols designed for nocturnal owls (Takats et al. 2001) can be effectively adapted to survey for diurnal northern pygmy owls, by conducting breeding surveys during daylight hours (06:00-21:00). Response rates appear to vary little throughout the day and throughout the survey period (mid-March to late-April).

Recommendation #5 – Account for spatial dependencies in habitat selection modeling.
Failure to account for autocorrelation can lead to erroneous assumptions with regard to the strength of effect and significance of predictors. Adopting autologistic regression in future wildlife-habitat analyses will result in the production of better fitting models, more accurate reflection of variable effects in model outcomes, and improved predicted probability maps.

Recommendation #6 – Maintain current Alberta status designations.
Currently both species are ranked as 'sensitive' in Alberta (CESCC 2001). Provincial status rankings are based on seven key criteria, including: population size, number of occurrences, distribution, threats to populations and threats to habitat. In support of this designation, our study has shown that both owls are widely distributed with very low estimated densities and population sizes. Similarly, habitat attributes required by both owls are also preferred by the forest industry, indicating a potential threat.

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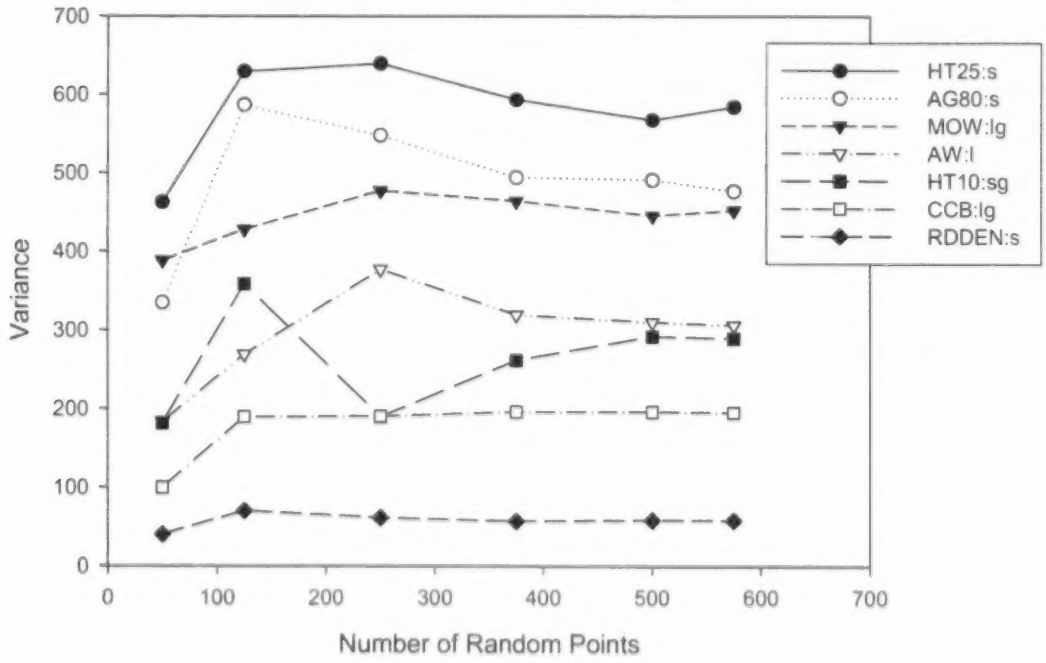
8.0 APPENDIX 1

Habitat Model Extrapolation Determination

To determine the number of random locations required to adequately represent the range of habitat availability across the landscape, we calculated the variances of seven model variables (HT25, AG80, MOW, AW, HT10, CCB, RDDEN) at five increasing intervals of random points (50, 125... 575). Variances were then plotted against the set of random points. The number of random points at which most variances levelled out, was deemed the appropriate number of locations to use to represent habitat availability across the study area. This number was approximately 550 random points; roughly equal to the number of sites visited for model determination. Using this technique, 500 sites were shown to adequately represent the observed landscape variability for a grizzly bear (*Ursus arctos*) study in the central Rocky Mountains, Alberta (Stevens 2002).



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